

International GPS Service - Life without SA

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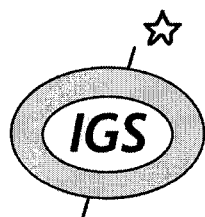
Christoph Reigber,

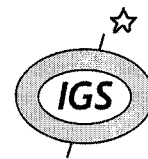
GeoForschungsZentrum, Potsdam, Germany

ION GPS 2000

Salt Lake City

September 20, 2000





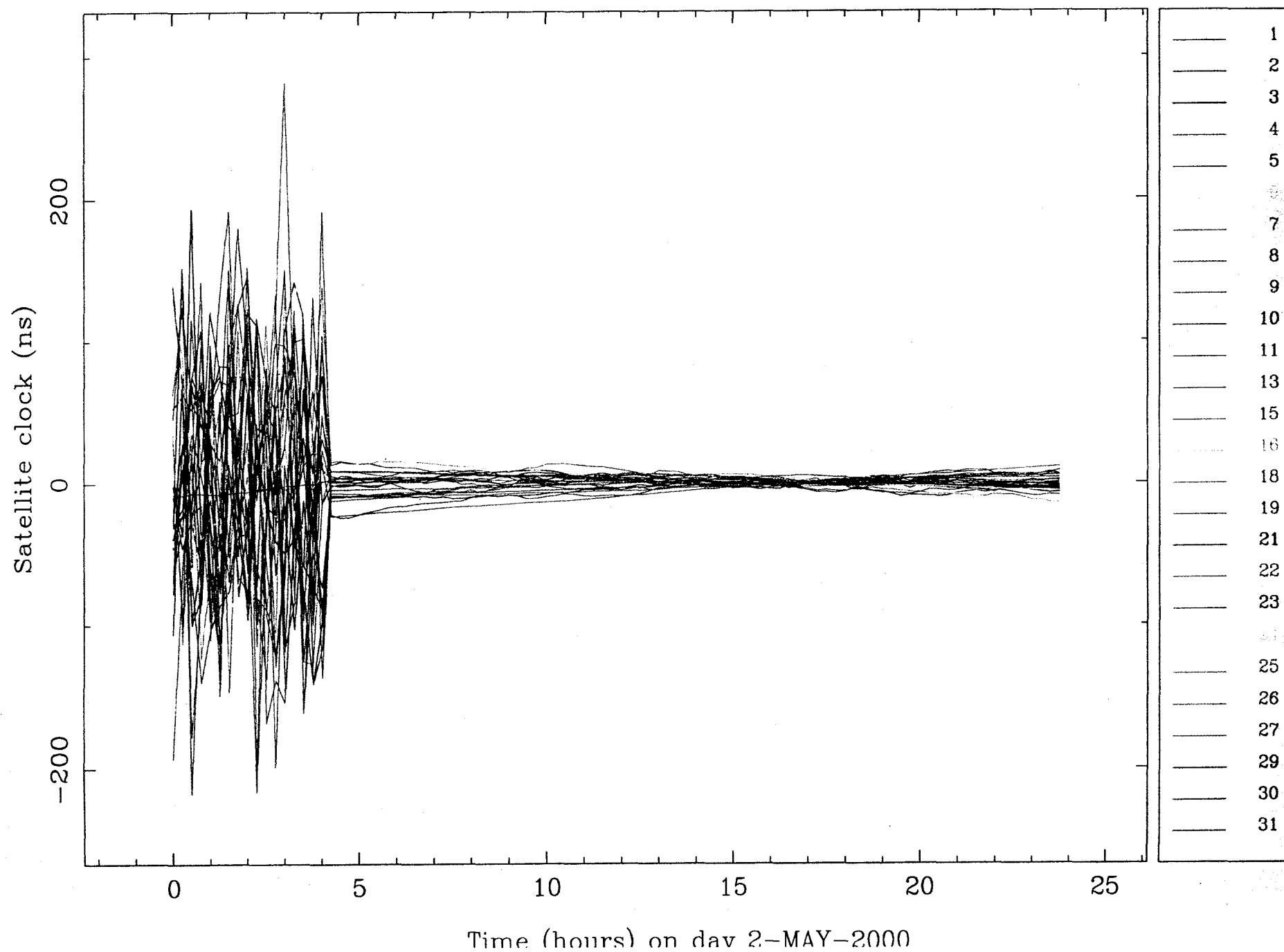
IGS Mission & Objectives

To provide a service to support geodetic and geophysical research activities, through GPS data and data products.

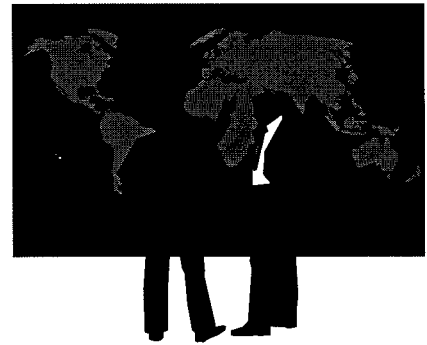
- Data from an international network of over 200 stations are used to produce:
 - High accuracy GPS satellite orbits
 - Coordinates and velocities of the IGS tracking stations
 - GPS satellite and tracking station clock information
 - Earth rotation parameters, ionospheric, tropospheric information

**SA off plot, Wk 1060, day
2, 5/2/2000**

GPS Satellite clock behavior minus offset and drift

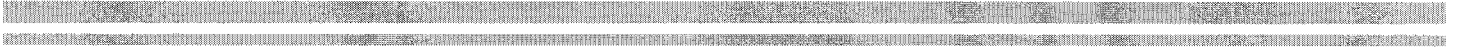


IGS Organization



- Recognized as a scientific service
- Advocate an *open data policy*
- Network of over 200 permanent precision geodetic receivers produce GPS data on a continuous basis, ~50 report hourly
- More than 90 contributing organizations
- Approved activity of the International Association of Geodesy (IAG) since January 1, 1994.
 - Member of Federation of Astronomical and Geophysical Data Analysis Services, 1996
- IUGG and ICSU recognition
 - International Union of Geodesy and Geophysics
 - International Council of Scientific Unions

IGS Org cartoon



".... TO SUPPORT GEODETIC AND GEOPHYSICAL RESEARCH
ACTIVITIES THROUGH GPS DATA & PRODUCTS...."



ORGANIZATION OF THE INTERNATIONAL GPS SERVICE



INTERNATIONAL GOVERNING BOARD



Global Data Centers

**Analysis Center
Coordinator**

**Operational & Regional
Data Centers**

INTERNET

Telephone - Modem, Radio Links

Analysis Centers

**Global Network
Associate Analysis Centers**

**Regional Network
Associate Analysis Centers**

USERS
Practical, Custom,
Commercial, Governments,...

IGS Projects and Working Groups

Reference Frame Densification
Precise Time Transfer
Low Earth Orbiters
Ionosphere
Atmosphere
Sea Level
GLONASS Pilot Service Project

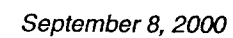
Central Bureau
Management, Network Coordinator,
Central Bureau Information System

GPS Stations

<http://igscb.jpl.nasa.gov>

IGS complete, hourly, & high rate maps

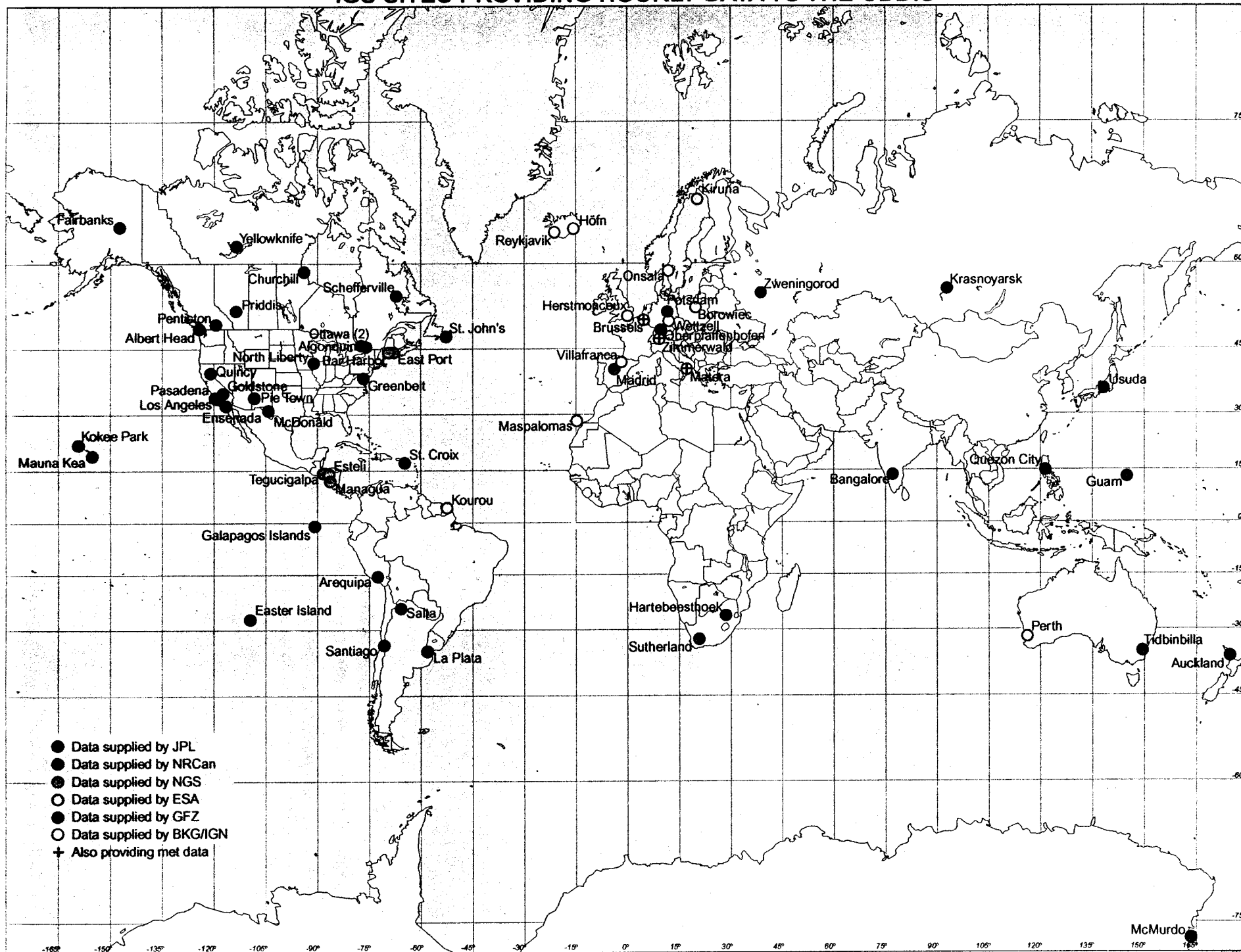
<http://igscb.jpl.nasa.gov>



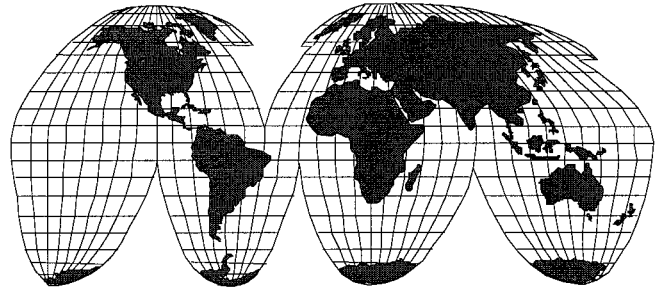
<http://igscb.jpl.nasa.gov>



IGS SITES PROVIDING HOURLY DATA TO THE CDDIS



WHY IGS?



Key factors in formation of IGS

- All geodynamics and geodetic organizations realized the potential of GPS by early 90's
- Motivating goal: millimeter positioning in support of science anywhere in the world
- Not one agency can nor should assume the capital investment & recurring operations costs for the entire infrastructure
- Join with key international partners to form federation, define cooperation, set standards, science quality driven
- Implement a global civilian GPS tracking system for science and research

Products Chart

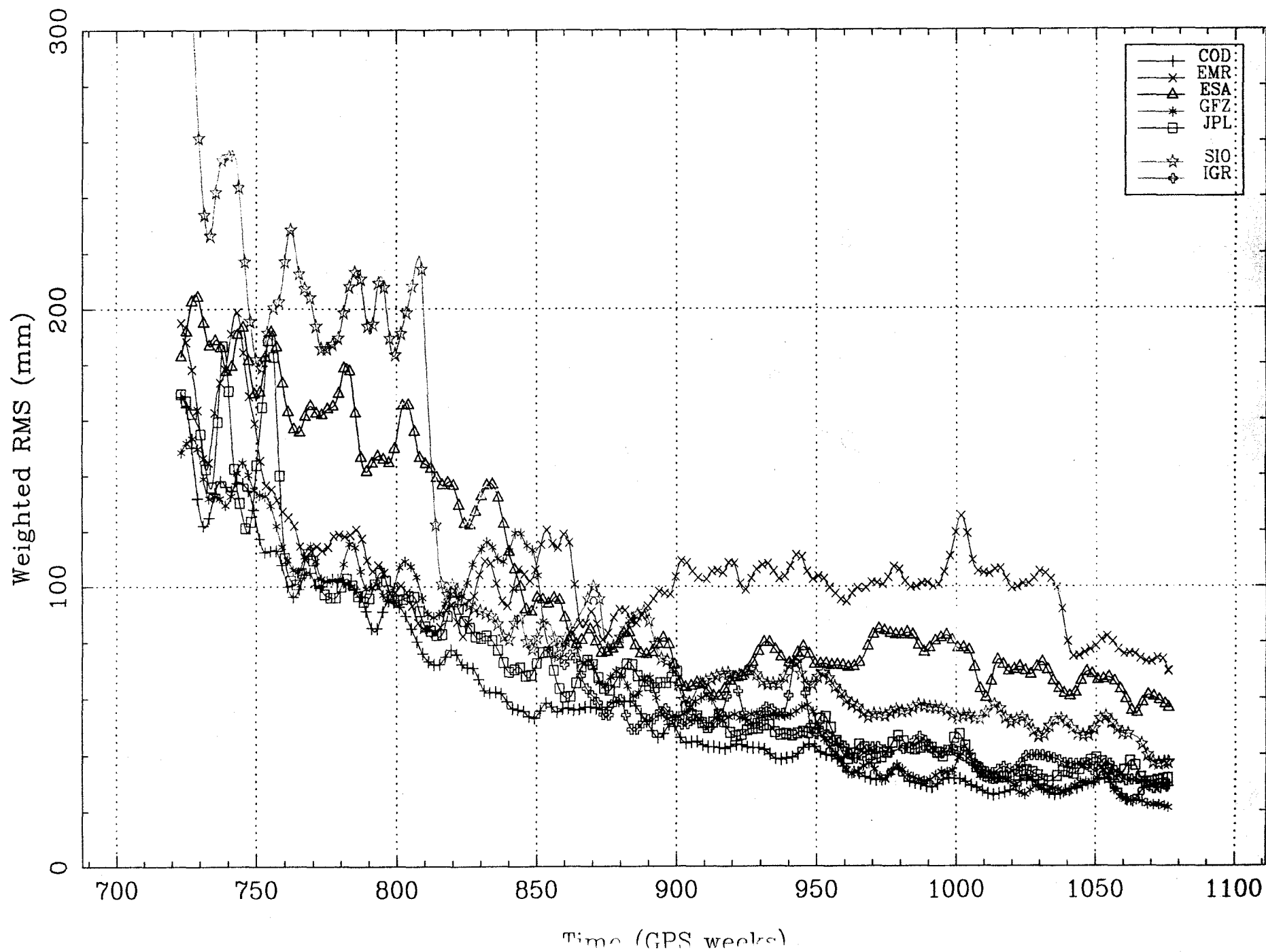




IGS PRODUCT Table

IGS Combined Product Precision

Product	Available	Interval	Precision	
<u>Satellite Orbits&clocks</u>			<u>orbits</u>	<u>clocks</u>
Predicted	Real-time	15 min	50 cm	30 ns
Rapid	17 hours	15 min	10 cm	.5 ns
Final	12 days	15 min	5 cm	.3 ns
<u>IGS Combined (Prelim.) Station</u>			<u>Positions</u>	<u>Velocities</u>
Weekly solutions	2-4 weeks	7 days	3-5 mm	1-3mm/y
<u>Earth Rotation Parameters</u>			<u>parameters</u>	<u>rates/LOD</u>
Rapid PM	17 hours	1 day	.2 mas.	.4 mas/d
Final PM	12 days	1 day	.1 mas	.2 mas/d
Rapid UT /LOD	17 hours	1 day	.10 ms	.06 ms/d
Final UT /LOD	10 days	1 day	.05 ms	.03 ms/d
Tropospheric ZPD	<4 weeks	2 hours	4 mm	
Ionosph. grid TEC	<4 weeks	2 hours	1 TEC unit	(~10cm)



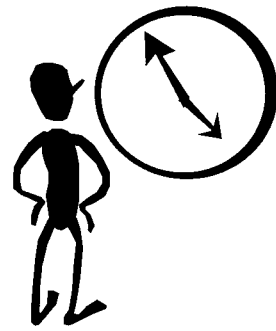
Orbit Improvement



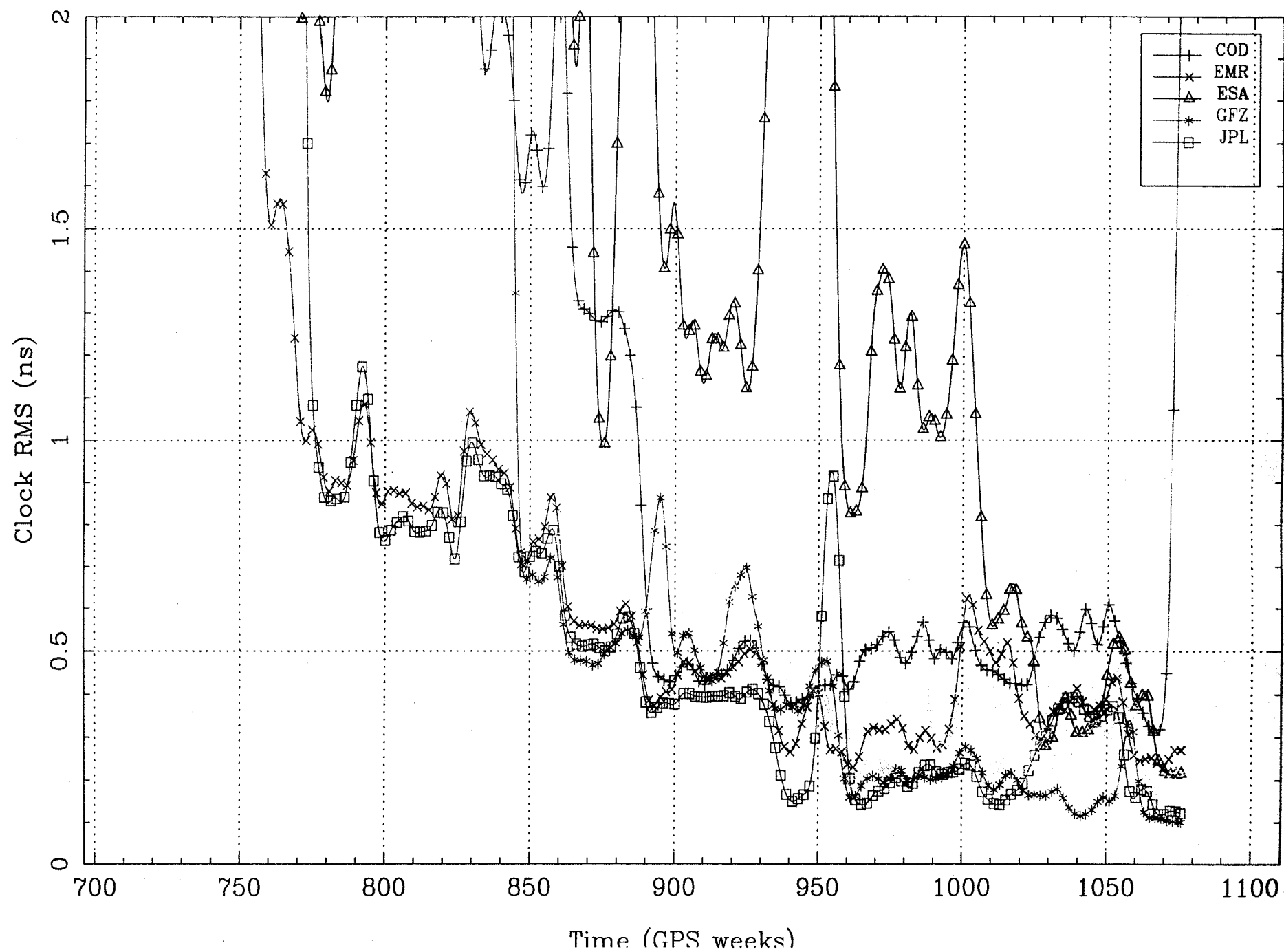
IGS Projects & Working Groups

- **Precise Timing**
 - Develop operational strategies to exploit GPS measurements for improved accurate time and frequency comparisons world
- **LEO Project**
 - IGS Network component, obvious infrastructure to support robust, high-rate, low latency data requirements
 - Other applications require timely availability of data (seconds to hourly)
- **IGLOS-PP**
 - GLONASS for geodetic and geophysical applications
- **Tropospheric**
- **Reference Frame Densification**
- **Ionosphere**
- **Sea Level monitoring initiative**

Life with SA



- Selective Availability, dithering of the GPS satellite clocks, does not impact *classic* IGS products or applications
- IGS predicted ephemerides provide good satellite orbits, but unable to predict corresponding satellite clocks
 - IGS satellite orbits and clocks:
 - » Predicted 50cm 150 ns
 - 36 hours based on Rapid
 - 9 hours based on 'Ultra', subdaily
 - » Rapid Products 10cm 0.5 ns
 - Within 17 hours after last observation
 - » Final Products 5cm 0.3 ns
 - 13 days on average
- IGS Ultra products not yet official
 - Hourly data and twice daily IGS AC submissions



Precise Point Positioning

- Daily Precise Navigation Summary using the corresponding Center orbit positions and satellite clock corrections at 15 min intervals.
- Consistency evaluation

Each line gives the daily station RMS w.r.t. the estimated coordinates for the Latitude, Longitude and Height components.

CLK - Satellite clocks used.

EPO - Number of satellite clock epochs available for that day.

Units: centimetres.

Table 5.1076.0 GPS week: 1076 Day: 0 MJD: 51776.0

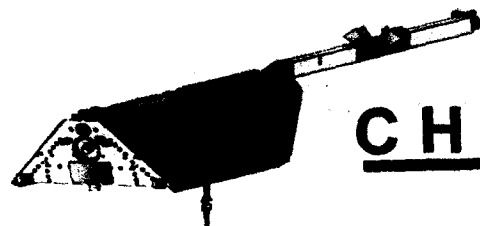
CENT	CLK EPO	BRUS			TOW2			WILL		
----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
cod	cod 2659	3	4	7	5	6	8	2	3	4
emr	emr 2554	3	3	6	2	3	8	2	3	4
esa	esa 2372	6	4	9	2	2	5	2	3	4
gfz	gfz 2663	2	2	7	2	2	6	1	2	3
igc	igc 2688	2	2	6	2	2	6	2	3	3
igr	igr 2688	3	3	7	3	3	5	2	2	5
igs	igs 2688	2	2	6	2	2	6	1	2	3
jpl	jpl 2576	3	3	7	2	1	5	2	3	4

Life with SA (2)

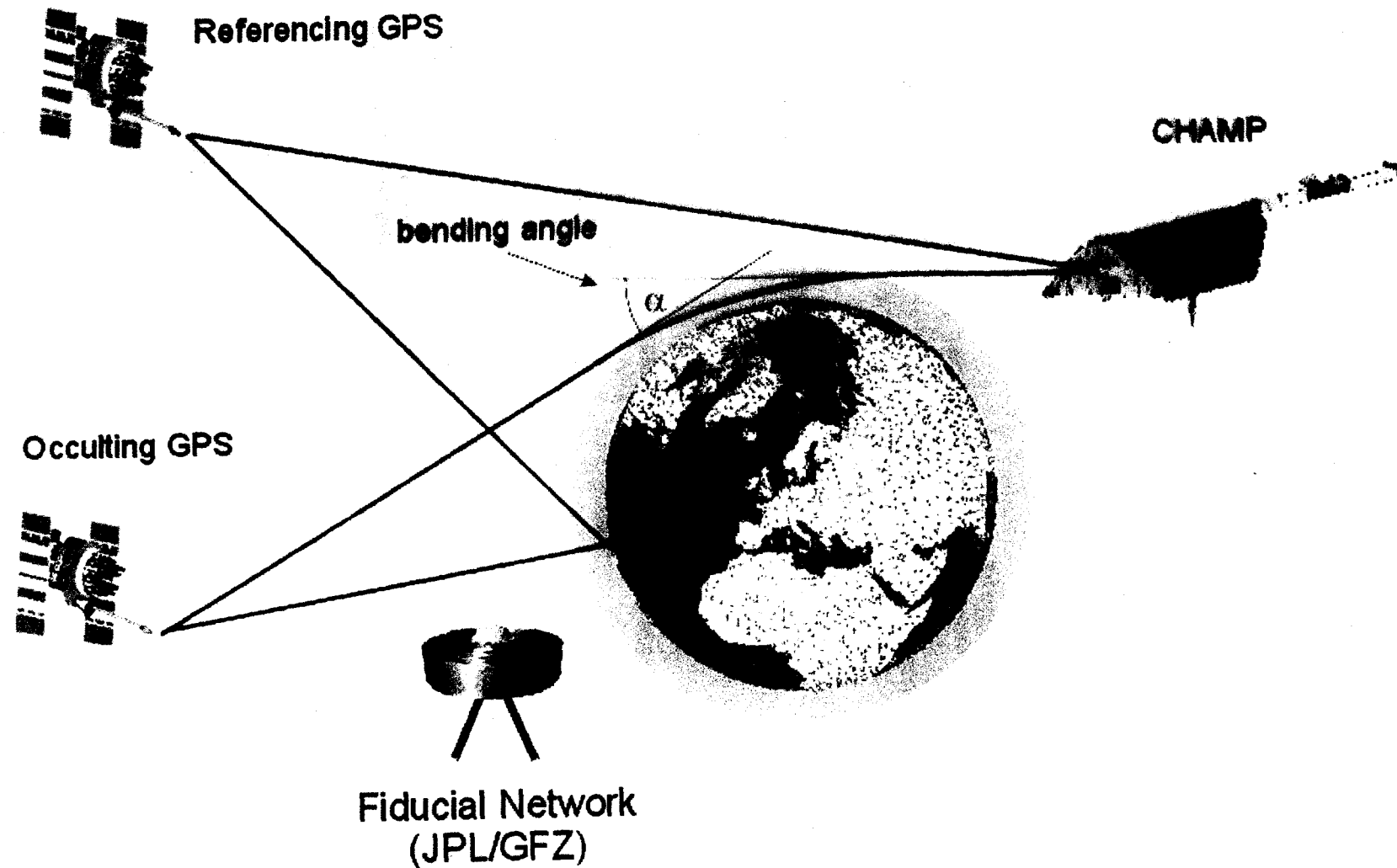
- Precise Timing Project drove the effort for IGS time scale, and IGS combined clock solutions at 5 min intervals, Jan '00
 - IGS orbit solutions in .sp3 format 15 min
 - 5 min clocks afford isolated user positioning at ~5 cm level with IGS products fixed (see ppp example)
- Support for Low Earth Orbiting missions required high-rate GPS observations to remove SA effect
 - Low latency (<15min) for precise orbit determination at standard obs rate, 30s
 - High rate observations (1Hz) for clock solutions between ground-LEO, needed for atmospheric occultation applications

CHAMP Occult. slide





CHAMP *Geometry of GPS limb sounding with CHAMP*



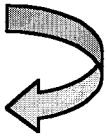
Life without SA

- Plans for a combined ***predicted*** clock will greatly enhance the utility of the IGS predicted orbit
 - Implemented by USNO July 31, 2000, experimental basis
 - Aligned to GPS broadcast time
 - Should be possible to produce IGS satellite orbits and clocks:
 - » Predicted 50cm few ns
 - Using the previous hour of clock estimates to predict the next hour one can obtain an accuracy of about 1.7 ns
- GPS clocks this accurate in real time need
 - Hourly data and instantaneous analysis
 - Handling the variation of SV transmitters

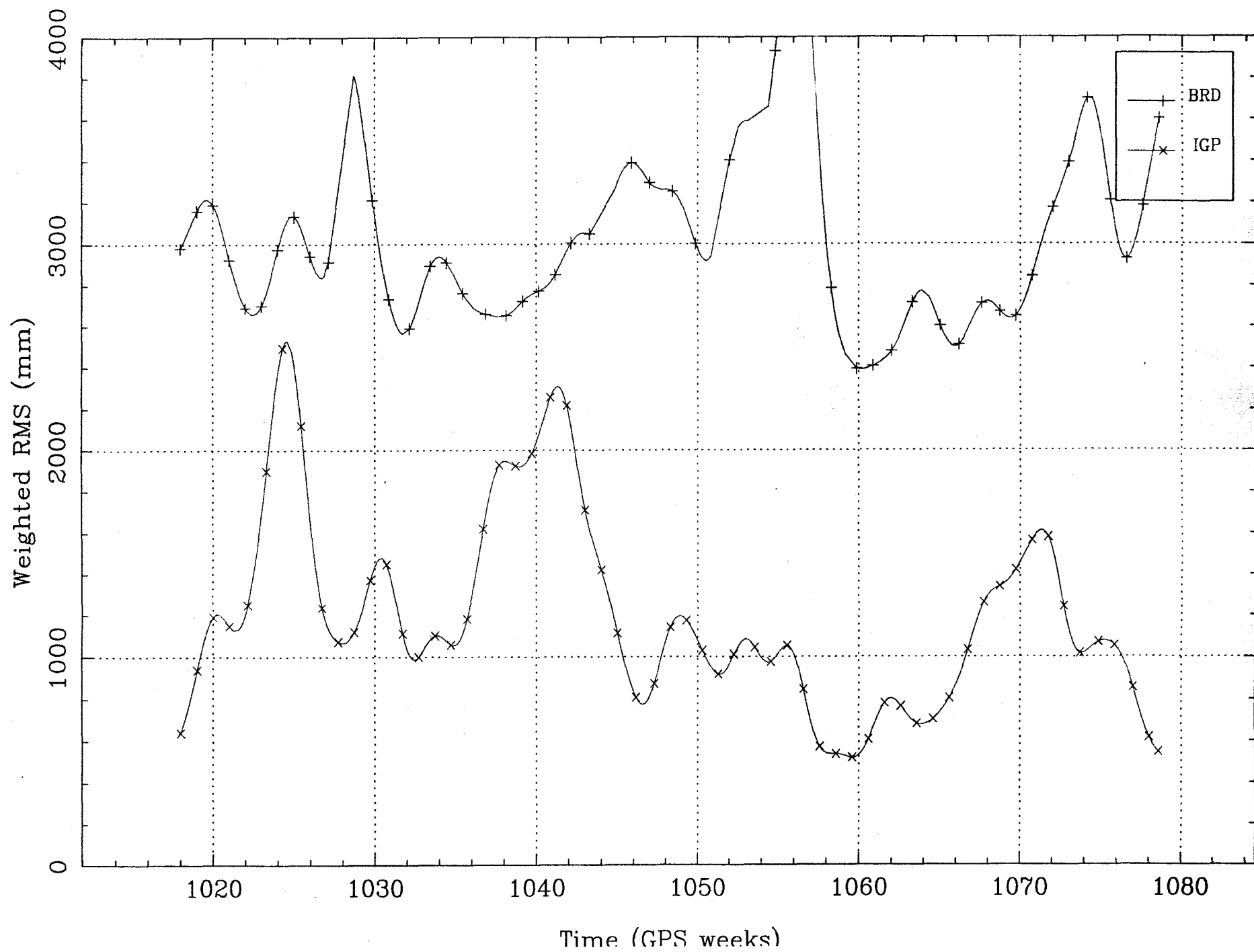
LEO Missions

- IGS will support Low Earth orbiting missions (LEO) which carry on-board GPS flight receivers, this requires
 - low latency ground network
 - operating with a subset of stations at a higher rate (0.1 - 1 Hz, or 10 - 1 sec samples)
- LEO Missions
 - CHAMP successfully launched July 15
 - Future SAC-C, GRACE, JASON, ICESat, FEDSat, COSMIC,
- The removal of SA greatly decreases the impact on the IGS infrastructure to meet LEO and other high-rate requirements
 - Impact reduced from a factor of ~30 to a factor of ~10

Summary

- SA off greatly simplifies processes for real time and near-real time applications
 - IGS Network/Data operators relieved
- IGS predicted orbits are a factor of 10 improvement over the Broadcast Ephemeris
 - Brd ~ 300 cm, <30ns
 - IGS Predicted ~ 50 cm, ~ few ns

(realizing the combined predicted clock)
- Significant effort needed to realize IGS time scale consistent with predicted UTC
 - Day-to-day stability and day boundary
 - Calibration of equipment
- Using IGS predicted orbits and clocks fixed, single user applying PPP should achieve decimeter level positioning results



For more information

URLs

- IGS Central Bureau
 - Visit our exhibit for more information
 - IGS users Forum this evening
 - <http://igscb.jpl.nasa.gov>
- IGS Analysis Center Coordinator
 - <http://www.cx.unibe.ch/aiub/acc.html>
- IGS Precise Timing project link
 - <http://maia.usno.navy.mil/gpst.html>
- IGS Global Data Centers
 - <http://cddis.gsfc.nasa.gov/data.html>
 - <http://lox.ucsd.edu/>